The Transmission of Eurozone Shocks to CEECs*

Peter Benczur[†], Miklos Koren[‡] and Attila Ratfai[§]

June 2004

Very preliminary

Abstract

This paper investigates the contribution of external shocks to business cycle volatility in countries of Central and Eastern Europe, the role of different transmission channels, and the evolution of these patterns through time. The main focus is on the role of shocks originating from the Euro-zone. In a dynamic empirical model of shock transmission, it uses an instrumental variable approach to identify the relative importance of financial versus goods market channels in the data.

The findings show that while external shocks explain a sizeable fraction of forecast error variance in CEE countries, most of the variation stems from local disturbances. As indicated by the negligible contribution of the covariance term to total forecast error variability, financial and goods market channels of shock transmission are orthogonal to each other in most countries. Countries in which some interaction between the two channels appears to be present are Hungary, Russia and Slovakia.

The Baltic countries excluded, the financial channel of shock transmission is more important in countries with more flexible exchange regime. The financial channel transmission dominates in the Czech Republic, Estonia, Lithuania, Romania, Russia and Slovenia; and the goods market channel is particularly important in Croatia, Hungary, Latvia, and to some degree, Slovakia. While there is no substantial difference between new member states and non-members in the contribution of the financial markets channel, the goods market channel is more powerful in new member states.

Keywords: Business cycles, International shock transmission, Central and Eastern Europe

JEL Classification: E32

*We thank Ayhan Kose for helpful comments. Financial support from GDN and CEU is also acknowledged. The views expressed herein are ours and have not been endorsed by MNB, CEU, CERGE-EI or the GDN.

†Magyar Nemzeti Bank and Central European University

‡Harvard University and Institute of Economics, Hungarian Academy of Sciences

§Central European University

1 INTRODUCTION

The 1990s saw a global movement towards market-based economies, an overall trend of trade and financial liberalization, and increasing integration of the world economy. This paper is specifically concerned with uncovering how the economies of Central and Eastern Europe (CEE) are integrated with the Euro-zone. The main questions we ask are the following. How much of economic volatility in CEE countries can be explained by shocks originating in the Euro-zone? What is the relative importance of goods and financial markets in transmitting exogenous, including Euro-zone shocks? Are there additional important channels of (dis)harmonization of shocks - like local accommodating or counteracting local macroeconomic policies?

First, regional integration is closely influenced by the nature of shock transmission between the regions. In the relation of the Euro-zone and CEE economies, this is dominantly a one-way avenue, from the large center to the small periphery. If fluctuations in the periphery are largely attributable to shocks originating in the center, then there is scope for coordinated reactions to these shocks. Having a dominant role of common shocks, however, is insufficient to justify common policies; the extra condition is that these shocks should have similar effects on relevant variables. Observing significantly different effects, on the other hand, is not necessarily bad news for integration, since it may also indicate a self-correcting mechanism among regions.

Consider now a negative demand shock in the Euro-zone. Such a shock is likely to reduce the demand for goods in CEE economies, thus have a contractionary effect in CEE economies through the trade channel. The importance of this channel of shock transmission is expected to increase with integration. Depressed demand in Europe, on the other hand, can also induce a capital outflow from the Euro-zone, seeking more profitable investment opportunities, potentially in CEE countries. This means that the effect through financial markets can be completely the opposite as through goods markets. Moreover, domestic policies may also react to this external shock. Though the policy channel may be hard to identify and separate, a decomposition of transmission into financial and goods markets effect is a natural and important first step towards understanding the interdependence of the Euro-zone and CEE economies. It can also hint policymakers where to focus their policy response. If shocks are dominantly transmitted via the goods market, then they are best offset by policies affecting the same market.

In addition, within a monetary union, trade links are likely to increase and this effect is potentially large. This extra trade is typically assumed to be of an intra-industry type. One would also expect higher levels of financial integration, which may have a positive effect of specialization via inter-industry trade. Finally, a monetary union involves a fully accommodating monetary policy. All these factors can affect the strength and nature of shock transmission. If we look at different transition countries at different times, there is substantial variation in the degree of trade, financial, and legal harmonization with the EU. Using cross-country experience during the accession period, we may get a picture of how these separate factors influence the transmission of shocks. Another relevant difference among accession countries is their exchange rate and monetary regime, though these may be correlated with the degree of financial integration. The exploration of potential differences in transmission along this dimension further helps predicting transmission within the EMU. Moreover, based on the comparison of fixed versus flexible exchange rate countries, we can access the implications of an early adoption of the Euro. For example, if the choice of the exchange rate regime does not seem to add anything to measures of integration, then the early adoption of the Euro may have very little effect on shock transmission.

2 BACKGROUND

In this project, we investigate the contribution of EU shocks to CEEC volatility, the role of different transmission channels, and the evolution of these patterns through time. The degree of business cycle co-movement among Central and Eastern European (CEE) economies has attracted the attention of researchers in the Optimal Currency Area literature. Kocenda (1999) uses panel unit root techniques to examine if transition countries converge to each other over time. He finds strong convergence in industrial output among the Czech Republic, Hungary and Poland, but with the other countries. An alternative approach is pursued by Fidrmuc and Korhonen (2001). In a Blanchard-Quah framework, they identify structural demand and supply disturbances in bivariate structural VAR models of output growth and inflation in Euro-zone and EU accession countries. Analyzing the cross-country correlation between these shocks they find, among others, that shocks in Estonia, and Hungary are highly correlated with those in the Euro-zone. The correlation with the Euro-zone in the raw data is highest for Hungary, Estonia and Slovenia. Fidrmuc (2001) documents that business cycle convergence between CEE and EU countries is primarily related to intra-industry trade.

Canova (2003) represents an important departure from the traditional literature of cross-country business cycle synchronization. He develops a two-stage dynamic model of the macroeconomy and applies it to studying the effect of US shock to six economies in Latin America. In a structural VAR framework, he identifies four distinct structural shocks originating in the US. Then he feeds the identified shocks into Latin American country-specific, reduced form VARs and investigates the size and the persistence of the response of domestic variables. He makes a distinction between financial and goods market transmission channels associated with the reduced form response in domestic interest rate and terms of trade, respectively, to structural US shocks. Among others, the results show that synchronization in inflation in response to US shocks is significant, while it is much less in output responses. The exchange rate regime does not matter for the nature of transmission. The relative importance of the asset versus the goods market transmission depends on the type of shock.

Abeyshinge and Forbes (2001) model the trade-growth channel in a structural VAR framework of multilateral trade relationships. Using carefully selected identification restrictions, they find significant cross-country multiplier effects of country specific shocks. Sometimes even small shocks can get magnified through the complex international trade matrix of seemingly unrelated national economies. A natural next question concerns the role of integration as a determinant of cross-country differences in shock transmission. Heathcote and Perri (2001) explore the link between financial integration and international correlation of aggregate variables. They first document both a substantial drop in the correlation of US, Japanese and European macro variables, and an increase in international asset diversification among these economies, from the 1970s to the 1990s. Then they offer an explanation in a theoretical model, in which increased international diversification is an endogenous response to a decline in the correlation of the underlying structural shocks, and reinforces the decrease in international co-movements.

Though Heathcote and Perri (2001) do not consider exogenous changes in the level of financial integration, a natural extension of their approach is to ask whether such an increase would also lead to less synchronization. Kalemli-Ozcan, Sorensen and Yosha (2001) pick up the topic empirically; they find that higher specialization leads to less symmetry of fluctuations among US regions, and financial integration promotes specialization. According to the debated but still undefeated evidence of Rose (2000), monetary unions lead to substantial extra trade. Since a traditional criterion of currency unions is the co-movement of fluctuations, these findings raise concerns whether the pre-union level of correlations would be maintained within the union. In order to separate these effects, one needs to decompose the macro correlations into the contribution of trade, financial and policy integration.

3 CHANNEL DECOMPOSITION

The conditional analysis of this project is agnostic about shocks at the sector and country level, it focuses instead on external shocks and their transmission. It also uses the same CEEC data analyzed in the previous project. The key bottleneck appears to be the terms of trade variable, which is missing from most of the standard macro data sources. We are sure, however, that national central banks do posses this information, so we can obtain these series by directly contacting their staff. An alternative is to use the real exchange rate instead of the terms of trade.

The first econometric question is the identification of Euro-zone shocks. Here we draw on the advances in the large literature using structurally identified VARs to examine the aggregate effects of unexpected monetary innovations. The work that applies the insights of this literature to area-wide macroeconomic shocks in the Euro-zone is Peersman and Smets (2001). They utilize the identification strategies in Christiano, Eichenbaum and Evans (2000), Gali (1992), Kim and Roubini (2000) and Leeper, Sims and Zha (1998) to study the dynamic response of macroeconomic variables primarily to monetary policy shocks. To enhance the robustness of the procedure, we follow Peersman and Smets in the identification strategy and employ alternative identification approaches to distill Euro-zone shocks from identified VARs. In fact, one can obtain the variance decomposition results even with reduced form Euro-zone shocks, as structural form shocks are linear combinations of reduced form shocks, and as we shall see, the variance decomposition is invariant to linear combinations.

Given a time series of Euro-zone shocks, the next step is to model their transmission to CEECs. Assume that foreign shocks can enter domestic variables only through international financial or goods markets. In any of those markets, shocks can enter as "quantity" or "price" signals: i.e. net capital inflow vs. domestic interest rates, and net exports vs. terms of trade. For a small open economy, we may assume that the dominant transmission channel is always the price signal. We will also test these simplifying assumptions.

Now consider a multivariate structural VAR representation of the stationary transformations of interest rate (it), terms of trade (tt_t) or the real exchange rate (rer_t), inflation (π_t), output (y_t), net capital flows (cf_t) and net exports (nx_t), specified separately for each country j. Omitting country-specific parameter indices for convenience, one can write the model in terms of the vector of endogenous variables $x_t = (i_t, tt_t, \pi_t, y_t, cf_t, nx_t)$ as

$$x_t = Ax_t + B(L)e_t + C(L)x_t + u_t. \tag{1}$$

Here e_t is a vector of foreign shocks impacting on the interest rate and the terms of trade as well. $C(L)$ is a pth degree matrix polynomial in the lag operator L with $C(0) = 0$ and $B(L)$ is a rth degree matrix polynomial in the lag operator L with $B(0) \neq 0$. The diagonal elements of A are normalized to zero. The off-diagonal elements of A then capture the contemporaneous impact of structural shocks on the endogenous variables in the system.

As explained above, the variables π_t, y_t, cf_t, nx_t are interpreted as being affected only by domestic shocks. It means that the corresponding rows of the $B(L)$ vector, $B_3(L), \ldots B_6(L)$, are identically zero. All the transmission of foreign shocks is through i_t and tt_t (or rer_t) Under standard regularity conditions, the structural model is transformed to the reduced form autoregressive one as

$$x_t = G^{-1}B(L)e_t + G^{-1}C(L)x_t + G^{-1}u_t = K(L)e_t + H(L)x_t + \varepsilon_t, \tag{2}$$

where $G = I - A$. Finally, from $x_t = W(L)K(L)e_t + W(L)u = S(L)e_t + W(L)u_t$ with $W(L) = (I - H(L))^{-1}$ and $S(L) = W(L)K(L)$, the Wold moving average representation, the infinite order, structural form moving average representation is obtained as

$$x_t = S(L)e_t + M(L)u_t, \tag{3}$$

where $M(L) = W(L)G^{-1}$. This form of the model is of particular interest for model identification and economic inference.

The estimation of the country-specific reduced form model in (2) is carried out by equation-by-equation OLS. To take advantage of the panel structure of the data, as an alternative, we also estimate a region level model with imposing cross-country restrictions on the reduced form dynamic parameters. The panel approach amounts to assuming a common $K(L)$ and/or $H(L)$ matrix across the different countries. The data used here are essentially the same as the ones utilized in the first part of the project.

The primary question of interest is whether we can infer anything about $B_1(L)$ and $B_2(L)$ from the reduced form estimates - i.e. the transmission of foreign shocks through the interest rate ("asset market") and the terms of trade ("goods market") channel.

We next need to decompose the impulse response of any domestic variable to a given foreign shock into the contribution of the two channels of transmission. Omitting error terms, one can rewrite (1) as

$$\begin{pmatrix} x_{1t} \\ x_{2t} \\ X_{3t} \end{pmatrix} = \underbrace{\begin{pmatrix} 0 & a_{12} & A_{13} \\ a_{21} & 0 & A_{23} \\ a_{13} & a_{23} & A_{33} \end{pmatrix}}_{A} \begin{pmatrix} x_{1t} \\ x_{2t} \\ X_{3t} \end{pmatrix} + \begin{pmatrix} B_1(L) \\ B_2(L) \\ 0 \end{pmatrix} e_t + \begin{pmatrix} C_1(L) \\ C_2(L) \\ C_3(L) \end{pmatrix} x_t. \tag{4}$$

For the analysis of transmission channels, the structural form of the X_3 variables is in fact not necessary. We can thus solve out the contemporaneous part from the 4-dimensional X_3 block (multiply this part by $(I_{4x4} - A_{33})^{-1}$) and get a semi-reduced form

$$\begin{pmatrix} x_{1t} \\ x_{2t} \\ X_{3t} \end{pmatrix} = \underbrace{\begin{pmatrix} 0 & a_{12} & A_{13} \\ a_{21} & 0 & A_{23} \\ a'_{13} & a'_{23} & 0 \end{pmatrix}}_{A'} \begin{pmatrix} x_{1t} \\ x_{2t} \\ X_{3t} \end{pmatrix} + \begin{pmatrix} B_1(L) \\ B_2(L) \\ 0 \end{pmatrix} e_t + \begin{pmatrix} C_1(L) \\ C_2(L) \\ C'_3(L) \end{pmatrix} x_t. \tag{5}$$

The reduced form is then

$$\begin{pmatrix} x_{1t} \\ x_{2t} \\ X_{3t} \end{pmatrix} = \underbrace{\left(I - A'\right)^{-1} \begin{pmatrix} B_1(L) \\ B_2(L) \\ 0 \end{pmatrix}}_{K(L)} e_t + \begin{pmatrix} H_1(L) \\ H_2(L) \\ H_3(L) \end{pmatrix} x_t. \tag{6}$$

Denote the upper left elements of $(I - A')^{-1}$ by g^{11}, g^{12}, g^{21}, g^{22}, then

$$\begin{aligned} K_1(L) &= g^{11} B_1(L) + g^{12} B_2(L) \\ K_2(L) &= g^{21} B_1(L) + g^{22} B_2(L). \end{aligned} \tag{7}$$

Combining these with the X_{3t} block of (4):

$$K_3(L) = \left(a_{13} g^{11} + a_{23} g^{21}\right) B_1(L) + \left(a_{13} g^{12} + a_{23} g^{22}\right) B_2(L). \tag{8}$$

Based on this, the term $K_3(L) = G^{-1} B(L)$ in equation (2) is equal to $G_1 B_1(L) + G_2 B_2(L)$.

Here the first term is the total contribution of the interest rate channel (i_t), and the second corresponds to terms of trade. Moving to the MA reduced form in (3), we can repeat the same decomposition as $S(L) = S_1 B_1(L) + S_2 B_2(L)$. The previous decomposition splits the impact effect of foreign shocks by their channel, while this latter corresponds to the full dynamic effect.

To reach this decomposition, we need to identify some additional, though not all, structural parameters. Like in any identification problem, this requires making some restrictions on the structural form. One assumption has already been made: $B_3 = \ldots B_6 = 0$. This in fact is already useful a partial identification of the contemporaneous matrix A: we can estimate the X_3 part of the semi-reduced form 5 by using foreign shocks as instruments. This system is even over-identified, which allows for testing the assumption that external shocks do not affect the non-transmission variables directly. Once a_{13} and a_{23} are obtained, if we also have $g^{11}B_1$, $g^{21}B_1$, $g^{12}B_2$ and $g^{22}B_2$, then (8) and the MA terms from the reduced form (2) are sufficient for both the G- and the S- decomposition. In fact, having $g^{11}, g^{12}, g^{21}, g^{22}$ is sufficient for the decomposition, since the reduced form estimates of the VAR gives us $K_1(L)$ and $K_2(L)$, and (7) can be solved for $B_1(L)$ and $B_2(L)$.

This procedure is in fact very similar to Canova (2003), but it offers a more precise and transparent interpretation of the channel decomposition. First, Canova treats the reduced form coefficients ($K_1(L)$ and $K_2(L)$) of international shocks as the channel coefficients, instead of the structural parameters $B_1(L)$ and $B_2(L)$. As we shall see soon, these coefficients are identical under certain assumptions on the contemporaneous matrix A (yielding $g^{11} = g^{22} = 1$, $g^{12} = g^{21} = 0$). The problem, however, lies in the decomposition procedure: the relative size of K_1 and K_2 does not show the relative importance of the two channels in transmitting shocks to the non-transmission variables X_3 (it nevertheless measures the relative importance on the two channel variables themselves, as long as $B_i = K_i$ holds). The correct measure is $\left(a_{13}g^{11} + a_{23}g^{21}\right) B_1(L)$ versus $\left(a_{13}g^{12} + a_{23}g^{22}\right) B_2(L)$. Under the equality of $B_i(L)$ and $K_i(L)$, this becomes $a_{13}B_1$ versus $a_{23}B_2$. Since our procedure by instrumenting the last row of the semi-reduced equation (4) with the external shocks gives a_{13} and a_{23}, we can calculate the channel decomposition of shock transmission.

4 IDENTIFICATION

4.1 The "Cheap" Approach

The critical step remains the identification of the parameters $g^{11} - g^{22}$. It is easy to see that

$$\begin{pmatrix} g^{11} & g^{12} \\ g^{21} & g^{22} \end{pmatrix} = \left(I_{2x2} - \begin{pmatrix} 0 & a_{12} \\ a_{21} & 0 \end{pmatrix} - \begin{pmatrix} A_{13}a_{13} & A_{13}a_{23} \\ A_{23}a_{13} & A_{23}a_{23} \end{pmatrix} \right)^{-1}.$$

Suppose that there are no contemporaneous effects between the first two variables, i.e., i_t and tt_t. Then $a_{12} = a_{21} = 0$. Also suppose that the no-transmission variables $(x_3 \ldots x_6)$ do not have contemporaneous effects on the transmission variables. Then $A_{13} = A_{23} = 0$, so $\begin{pmatrix} g^{11} & g^{12} \\ g^{21} & g^{22} \end{pmatrix} = I_{2x2}$. Under these identifying assumptions, $B_1 = K_1$ and $B_2 = K_2$, so the reduced form effects of international shocks on the transmission variables are the same as the structural form effects. The procedure thus is to estimate the reduced form for i_t and tt_t, and the semi-reduced form for X_{3t}. The first two equations give us B_1 and B_2, while the latter four yields a_{13} and a_{23}. The full reduced form also gives us the MA matrix $H(L)$, which enables us to calculate $S = (I - H(L))^{-1} K(L)$.

Though these assumptions were sufficient for identification, they are far from being convincing. Their problem is that the two channel variables are the nominal interest rate and the real effective exchange rate, and it is hard to argue that these variables would not respond immediately to any other domestic variables. If the trade channel is represented by the terms of trade, it might be more reasonable to assume that certain contemporaneous effects are zero, but the financial markets channel remains unidentified, leaving the channel decomposition unidentified.

4.2 The Bivariate System

Like in a regular SVAR, one can explore the special structure of the error terms. Look back at (5) with the error terms included:

$$\begin{pmatrix} x_{1t} \\ x_{2t} \\ X_{3t} \end{pmatrix} = \underbrace{\begin{pmatrix} 0 & a_{12} & A_{13} \\ a_{21} & 0 & A_{23} \\ a'_{13} & a'_{23} & 0 \end{pmatrix}}_{A'} \begin{pmatrix} x_{1t} \\ x_{2t} \\ X_{3t} \end{pmatrix} + \begin{pmatrix} C_1(L) \\ C_2(L) \\ C'_3(L) \end{pmatrix} x_t + \begin{pmatrix} B_1(L) \\ B_2(L) \\ 0 \end{pmatrix} e_t + \begin{pmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{pmatrix}. \quad (9)$$

The part $B(L)e_t + u_t$ is in fact the structural error term, where instead of assuming the full orthogonality of its components, we assume that the Euro-zone shocks e_t cause a contemporaneous correlation between the error terms of the two channel. We can maintain, however, the orthogonality of the non-Euro-zone shocks, which means that the variance-covariance matrix is block-diagonal:

$$E[uu^T] = \begin{pmatrix} d_{11} & 0 & 0 \\ 0 & d_{22} & 0 \\ 0 & 0 & \Omega \end{pmatrix}.$$

The X_3 part is not necessarily diagonal, due to the semi-reduced form transformation (4)-(5). This gives us restrictions on the reduced form variance-covariance matrix Σ (of the reduced form VAR residuals):

$$\begin{aligned}
(I - A')\,\Sigma\,(I - A') &= E[uu^T] \\
\begin{pmatrix} 1 & -a_{12} & -A_{13} \\ -a_{21} & 1 & -A_{23} \\ -a'_{13} & -a'_{23} & I \end{pmatrix} \Sigma \begin{pmatrix} 1 & -a_{12} & -A_{13} \\ -a_{21} & 1 & -A_{23} \\ -a'_{13} & -a'_{23} & I \end{pmatrix} &= \begin{pmatrix} d_{11} & 0 & 0 \\ 0 & d_{22} & 0 \\ 0 & 0 & \Omega \end{pmatrix} \\
\begin{pmatrix} 1 & -a_{12} & -A_{13} \end{pmatrix} \Sigma \begin{pmatrix} -a_{12} & 1 & -a'_{23} \end{pmatrix}^T &= 0 \\
\begin{pmatrix} 1 & -a_{12} & -A_{13} \end{pmatrix} \Sigma \begin{pmatrix} -A_{13} & -A_{23} & I \end{pmatrix}^T &= 0 \\
\begin{pmatrix} -a_{21} & 1 & -A_{23} \end{pmatrix} \Sigma \begin{pmatrix} -A_{13} & -A_{23} & I \end{pmatrix}^T &= 0.
\end{aligned}$$

The first equation means one zero restriction, while the second and the third gives four each. In general, if the number of shocks in e_t is s, then we have $2s + 1$ restrictions. We need to find $2s + 2$ parameters altogether: $a_{12}, a_{21}, A_{13}, A_{23}$, which leaves us with the need of one extra identification restriction.

The second and third set of restrictions can also be given an instrumental variables interpretation. One can establish the following. Suppose that the error terms (u_{1t}, u_{2t}) and U_{3t} are orthogonal. Then the residuals from the identified X_{3t} block of the semi-reduced form (5) can serve as instruments for X_{3t} in both the x_{1t} and the x_{2t} structural equation (the key is that these residuals are orthogonal to u_{1t} and u_{2t}). This identifies A_{13} and A_{23}, leaving only a_{12} and a_{21} unidentified. With this procedure, we are back to a regular 2-variable SVAR in x_{1t} and x_{2t}, with a richer set of exogenous variables than just the lags of x_1 and x_2. Just like in the standard case, the orthogonality of u_{1t} and u_{2t} can give us one more restrictions. The last one can be then obtained as a zero restriction, a long-term restriction; or one can explore the $a_{21} - a_{12}$ curve, each combination offering a full channel decomposition (with separate impulse responses through the two channels, and a variance decomposition).

4.3 Long-Run Restrictions

In order to obtain this last restriction, we resort to long-run restrictions on the impact of certain shocks. So far we did not have to worry about the nature of Euro-zone: in particular, they could come from a reduced form VAR of the Euro-zone. This is because structural errors could be expressed as linear combinations of reduced form errors, and the channel decomposition is invariant to linear transformations of e_t: if $e_t' = Se_t$, then $B_1(L)$ becomes $B_1(L)S^{-1}$, and the channel decomposition remains

$$\begin{aligned} K_1(L)e_t &= g^{11}B_1(L) + g^{12}B_2(L) = g^{11}B_1(L)S^{-1}Se_t + g^{12}B_2(L)S^{-1}Se_t \\ &= g^{11}B_1'(L)e_t' + g^{12}B_2'(L)e_t' = K_1'(L)e_t'. \end{aligned}$$

Assume now that at least one component of e_t is identified as a structural shock, namely, a pure monetary disturbance. This case is interesting in itself as well, since we can get a picture of CEEC impulse responses to Euro-zone monetary shocks, and also split their effect between the two channels of transmission. Moreover, we can postulate that a monetary shock should have no long-run effect on the real effective exchange rate – just like demand shocks (temporary, nominal disturbances) should effect inflation but not output in the original Blanchard-Quah framework. This assumption seems plausible, moreover, it has bite in our sample, since the cyclical component of real effective exchange rates is highly persistent.

¿From stationarity, the long-run effect of any shock on any variable should be zero. The extra assumption of Blanchard and Quah is that a demand shock has no long-run effect on the *level* of output either. Correspondingly, if the stationary version of the real exchange rate is its change, then the long-run assumption is that the monetary shock should have no cumulated effect on the real exchange rate.

The problem with this approach is that it appears to give restrictions on the reduced form

VAR estimates $H, K\ (S)$, which are identified anyway:

$$\begin{pmatrix} x_{1i} \\ x_{2t} \\ X_{3t} \end{pmatrix} = \begin{pmatrix} K_1(L) \\ K_2(L) \\ K_3(L) \end{pmatrix} e_t + H(L)\, x_t + \varepsilon_t$$

$$\begin{aligned} x_t &= (I - H(L))^{-1} K(L)\, e_t + (I - H(L))^{-1} \varepsilon_t \\ &= S(L)\, e_t + (I - H(L))^{-1} \varepsilon_t \end{aligned}$$

and the long-run restriction is that

$$S(I) \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} x \\ 0 \\ X \end{pmatrix}.$$

The substitution of the identity matrix I into the lag polynomial $S(L)$ describes the cumulated effect of an innovation to e, which must yield a zero effect on x_{2t} if the innovation is purely monetary. It is equivalent to saying that $S(I)$ should have a zero element in its $(2, 1)$ position.

What would indeed help is a long-run restriction on *domestic* monetary shocks, since that would again give a constraint on the covariance matrix. Notice that one might have more than one "monetary" variable among the x_{it}s – we can assume that there are separate monetary shocks originating from both, and in fact the level of the real exchange rate should be invariant to both. This could yield even over-identification of our system.

Let us explore now the mechanics of such a long-run restriction. Recall that

$$x_t = S(L)\, e_t + (I - H(L))^{-1} \varepsilon_t = W(L)\, K(L)\, e_t + W(L) \left(I - A'\right)^{-1} u_t.$$

From (9), one can see that (using Maple, for example):

$$\left(I - A'\right)^{-1} \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} = \frac{1}{Det\,(I - A')} \begin{pmatrix} 1 - A_{23} a'_{23} \\ a_{21} + A_{23} a'_{13} \\ a'_{13} + a'_{23} a_{21} \end{pmatrix}.$$

The long-run restriction now becomes

$$W\left(I\right)_{row\ 2}\left(\begin{array}{c} 1-A_{23}a_{23}' \\ a_{21}+A_{23}a_{13}' \\ a_{13}'+a_{23}'a_{21} \end{array}\right)=0. \tag{10}$$

The nice feature is that we already now A_{23}, a_{23}' and a_{13}', so this is a restriction exclusively on a_{21}. This identifies the structural form of x_{2t}, and the orthogonality of u_{1t} and u_{2t} enables the identification of the x_{1t} equation (alternatively, we can obtain $a_{12}, \sigma_{u_1}^2, \sigma_{u_2}^2$ from the reduced form covariance matrix Σ.

Summing up: there is a recursive scheme of identification. (1) First we can estimate the x_{3t} semi-reduced form directly, by using the Euro-zone shocks e_t as instruments for the endogenous variables x_{1t} and x_{2t}. (2) We can test the over-identification, which checks whether foreign shocks have any direct influence on "non-channel" variables. (3) Then we can use the residuals from the x_{3t} equation as instruments for x_{3t} in the x_{2t} and x_{1t} equations. This means that we estimate a semi-reduced form

$$\begin{aligned} x_{1t} &= A_{13}'x_{3t}+B_1'\left(L\right)e_t+C_1'\left(L\right)x_{3t} \\ x_{2t} &= A_{23}'x_{3t}+B_2'\left(L\right)e_t+C_2'\left(L\right)x \end{aligned}$$

by instrumenting x_{3t} with the residuals. (4) A straightforward transformation gives us A_{23}, B_2 and C_2 from the semi-reduced form and a_{21}: $A_{23}=A_{23}'-a_{21}A_{13}'$ etc. The long-run restriction (10) thus expresses a_{21} as a linear combination of parameters already determined, which then identifies the structural form of the x_{2t} equation.(5) The structural form residuals from the x_{3t} and the x_{2t} equations identify the x_{1t} equation. Of course, the calculation of standard errors is still necessary, and requires computational efforts.

5 DATA

For nominal interest rates, the real effective exchange rate, net exports, inflation and GDP, we use the same data as Benczur-Ratfai (2004). Net capital flows are from IFS, world and eurozone variables are from IFS and ECB. [to be completed]

6 SPECIFICATION ISSUES

To ensure stationarity of the variables in the VAR specification, we carry out country-by-country, variable-by-variable unit root tests, and use the acceptable variant. A constant and a time trend is included on the right hand side of the VARs. [to be completed]

7 IMPULSE RESPONSE- AND VARIANCE-DECOMPOSITION

The channel decomposition also allows for a decomposition of domestic impulse responses and the variation of fluctuations as well. Impulse responses are set by (6)

$$\begin{pmatrix} x_{1t} \\ x_{2t} \\ X_{3t} \end{pmatrix} = \left(\begin{pmatrix} K_{11}(L) \\ K_{21}(L) \\ K_{31}(L) \end{pmatrix} + \begin{pmatrix} K_{12}(L) \\ K_{22}(L) \\ K_{32}(L) \end{pmatrix} \right) e_t + \begin{pmatrix} H_1(L) \\ H_2(L) \\ H_3(L) \end{pmatrix} x_t,$$

or its MA form:

$$\begin{pmatrix} x_{1t} \\ x_{2t} \\ X_{3t} \end{pmatrix} = \left(\begin{pmatrix} S_{11}(L) \\ S_{21}(L) \\ S_{31}(L) \end{pmatrix} + \begin{pmatrix} S_{12}(L) \\ S_{22}(L) \\ S_{32}(L) \end{pmatrix} \right) e_t$$

The first terms always correspond to the effect of foreign shocks through the first channel variable (financial markets – the interest rate), while the second represents the total contribution of the trade channel (the real exchange rate). This decomposition reflects the following counterfactual: suppose you shut down the first transmission channels, but everything else remains the same. Then the impulse response through the S_{i2} terms describes the corresponding effect of a foreign shock.

Let us turn to the variance decomposition now. It will not be an orthogonal decomposition, since $B_1(L)e_t$ and $B_2(L)e_t$ are in general correlated. Look at the decomposed version of the (AR) reduced form:

$$x_t = G_1 e_t + G_2 e_t + H(L)x_t + \varepsilon_t,$$

where $G_1(L)$ and $G_2(L)$ represents the split between the two channels. Inverting this yields

$$x_t = \underbrace{(I - H(L))^{-1} G_1(L)}_{N_1(L)} e_t + \underbrace{(I - H(L))^{-1} G_2(L)}_{N_2(L)} e_t + M(L)u_t.$$

Writing everything from here on in demeaned variables, we have

$$\begin{aligned} E[xx^T] &= E[(N_1(L)e)(N_1(L)e)^T] + E[(N_2(L)e)(N_2(L)e)^T] \\ &\quad + E[(N_1(L)e)(N_2(L)e)^T] + M(L)E[uu^T]M^T(L). \end{aligned}$$

This is the variance decomposition: the first term represents the variation coming entirely from the first transmission channel. The second term comes from the second channel, while the third and fourth are the interaction terms: $N_1(L)e_t$ is the impact of foreign shocks through channel 1, $N_2(L)e_t$ is the effect through channel 2, and they do have a correlation in general. If foreign shocks are defined to be serially uncorrelated, then the first three term in fact simplify to $N_1(L)E[ee^T]N_1(L)^T$ etc. The last term is the contribution of purely domestic shocks. Notice that a linear transformation of the Euro-zone shocks indeed leaves this decomposition unaltered, since the lag polynomials $N_1(L)$ and $N_2(L)$ get multiplied by the inverse transformation.

One remark on the possible inclusion of world, and not just Euro-zone shocks. Canova used variables like oil prices and some emerging market spreads. This we can also do. Notice that they should also be included in the Euro-zone VARs (no matter whether structural or reduced form). This was the purely Euro-zone shocks are orthogonal to these global factors, enabling a further split of variances according to Euro-zone versus global shocks. In fact, these global shocks can be merged into e_t in our current framework. It remains reasonable that they also enter exclusively through the same two channels. The only extra contribution of having such global terms is the further (partly orthogonal) decomposition, using the block-diagonality of the composite global and Euro-zone shocks' variance matrix $E[ee^T]$.

Finally, we need a strategy to estimate the effect of integration on transmission, and the relative importance of its channels. The particular questions we address here are the following: With the increase in integration during the 90s, do we also see any other systematic behavior in the strength of transmission? Is such an effect due to trade or financial integration, or accommodating domestic aggregate demand policies? Does the exchange rate or the monetary regime matter for the effect? A way to address these issues is to construct various measures of integration, and replace country differences in the transmission coefficients with integration measures, or monetary regime characteristics. Intuitively, it means the assumption that country-level, cross-section and time series differences in the effect of Euro-zone shocks on countries are due to different levels of integration or monetary regimes, after country size has controlled for.

8 RESULTS

Table 1 reports the results of the forecast variance decomposition of the six domestic variables into the contribution of the financial market channel (i), the goods market channel (rer), their covariance, and purely domestic shocks. While external shocks explain a sizeable fraction of forecast error variance in CEE countries, most of the variation stems from local disturbances. An interesting case is Bulgaria, where the post-hyperinflation period would give a dominant (near 80%) role for foreign shocks. This is also visible in the residual plot, and it is hardly surprising, given the large domestic shock of the hyperinflation and then the following currency board arrangement.

As indicated by the negligible contribution of the covariance term to total forecast error variability, financial and goods market channels of shock transmission are orthogonal to each other in most countries. Countries in which some interaction between the two channels appears to be present are Hungary, Russia and Slovakia. The sizeable negative figures for the covariance term here may indicate that the domestic impact of external shock are effectively hedged, perhaps through economic policy responses to these shocks.

The Baltic countries excluded, the financial channel of shock transmission is more important in countries with more flexible exchange regime. The financial channel transmission dominates in the Czech Republic, Estonia, Lithuania, Romania, Russia and Slovenia; while the goods market channel is particularly important in Croatia, Hungary, Latvia, and to some degree, Slovakia. While there is no substantial difference between new member states and non-members in the contribution of the financial markets channel, the goods market channel is more powerful in new member states.

Overall, eurozone and world shocks explain a non-negligible fraction of variance in CEE countries, and these effects are split by channels in a nontrivial way. There is also substantial variation in the degree of how much eurozone shocks and each channel matter.

9 References

Abeysinghe, T. and K. J. Forbes (2001): "Trade Linkages and Output Multiplier Effects: A Structural VAR Approach with a Focus on Asia," NBER Working Paper No. 8600

Benczur, P. and A. Ratfai (2004): "Fluctuations in Central and Eastern Europe. The Facts." Mimeo, Central European University

Canova, F. (2003): "The Transmission of US Shocks to Latin American Countries," CEPR Discussion Paper No. 3963

Christiano, L. and M. Eichenbaum and Ch. Evans (2000): "Monetary Policy Shocks: What Have Learned and To What End?," in J. Taylor and M. Woodford (eds.), Handbook of Macroeconomics, North-Holland

Fidrmuc, J. (2001): "The Endogeneity of Optimum Currency Area Criteria, Intra-Industry Trade and EMU Enlargement," BOFIT Discussion Papers No. 8

Fidrmuc, J. and I. Korhonen (2001): "Similarity of Supply and Demand Shocks between the Euro Area and CEECs," BOFIT Discussion Papers No. 14

Gali, J. (1992): "How Well the IS-LM Model Fit Postwar US Data?,"Quarterly Journal of Economics, pp. 709-738

Heathcote, J. and F. Perri (2001): "Financial Globalization and Real Regionalization," Working Paper 2001/5, Duke University

Kalemli-Ozcan, S., B. Sorensen and O. Yosha (2001): "Economic integration, industrial specialization, and the asymmetry of macroeconomic fluctuations," Journal of International Economics, pp. 107-137

Kim and Roubini (2000): "Exchange Rate Anomalies in the Industrial Countries: A Solution with A Structural VAR Approach," Journal of Monetary Economics, pp. 561-586

Kocenda, Evzen (1999): "Limited Macroeconomic Convergence in Transition Countries," CEPR Working Paper No. 2285

Leeper, Eric, Chris Sims and Tao Zha (1998): "What Does Monetary Policy Do?," Brookings Papers on Economic Activity, pp. 1-78

Peersman, Gert and Frank Smets (2001): "The Monetary Transmission Mechanism in the Euro Area: More Evidence from VAR Analysis," ECB Working Paper No. 91

Rose, Andrew K. (2000): "One Money, One Market: Estimating the Effect of Common Currencies on Trade," Economic Policy, pp. 9-45

Table 1: Forecast Error Variance Decomposition, 12 Quarter Horizon: by Country

	Financial	Goods	Covariance	Internal
	Bulgaria			
Interest Rate	0.083	0.116	-0.012	0.813
Real Effective Exchange Rate	0.073	0.044	-0.003	0.886
Net Capital Flows	0.015	0.127	-0.002	0.861
Net Exports	0.068	0.146	-0.003	0.789
GDP	0.070	0.035	-0.004	0.899
CPI	0.066	0.028	-0.001	0.906
average	*0.063*	*0.083*	*-0.004*	*0.859*
	Croatia			
Interest Rate	0.051	0.091	0.014	0.843
Real Effective Exchange Rate	0.015	0.197	-0.007	0.795
Net Capital Flows	0.071	0.031	0.009	0.889
Net Exports	0.002	0.411	-0.002	0.589
GDP	0.016	0.021	0.003	0.960
CPI	0.007	0.070	0.005	0.918
average	*0.027*	*0.137*	*0.004*	*0.832*
	Czech Republic			
Interest Rate	0.143	0.072	0.013	0.772
Real Effective Exchange Rate	0.449	0.000	0.001	0.550
Net Capital Flows	0.038	0.005	-0.002	0.959
Net Exports	0.071	0.018	0.003	0.908
GDP	0.034	0.023	0.002	0.941
CPI	0.101	0.018	0.002	0.880
average	*0.139*	*0.023*	*0.003*	*0.835*

Table 1: (continued)

	Financial	Goods	Covariance	Internal
	Estonia			
Interest Rate	0.034	0.255	0.122	0.590
Real Effective Exchange Rate	0.395	0.009	0.032	0.564
Net Capital Flows	0.130	0.013	-0.049	0.905
Net Exports	0.099	0.047	-0.092	0.946
GDP	0.033	0.031	0.010	0.927
CPI	0.175	0.178	-0.177	0.824
average	*0.144*	*0.089*	*-0.026*	*0.793*
	Hungary			
Interest Rate	0.030	0.449	-0.161	0.682
Real Effective Exchange Rate	0.441	0.372	-0.540	0.728
Net Capital Flows	0.266	0.125	-0.176	0.785
Net Exports	0.198	0.072	-0.187	0.917
GDP	0.431	0.330	-0.474	0.714
CPI	0.206	0.465	-0.484	0.813
average	*0.262*	*0.302*	*-0.337*	*0.773*
	Latvia			
Interest Rate	0.002	0.341	0.004	0.653
Real Effective Exchange Rate	0.139	0.063	-0.031	0.828
Net Capital Flows	0.045	0.070	0.026	0.859
Net Exports	0.094	0.111	0.053	0.742
GDP	0.031	0.009	0.008	0.953
CPI	0.039	0.121	-0.015	0.856
average	*0.058*	*0.119*	*0.008*	*0.815*

Table 1: (continued)

	Financial	Goods	Covariance	Internal
	Lithuania			
Interest Rate	0.057	0.259	-0.053	0.737
Real Effective Exchange Rate	0.380	0.017	0.011	0.592
Net Capital Flows	0.462	0.002	0.009	0.527
Net Exports	0.182	0.050	-0.006	0.773
GDP	0.082	0.393	-0.060	0.585
CPI	0.064	0.049	-0.024	0.910
average	*0.205*	*0.128*	*-0.021*	*0.687*
	Romania			
Interest Rate	0.324	0.029	-0.102	0.749
Real Effective Exchange Rate	0.219	0.072	0.019	0.690
Net Capital Flows	0.223	0.028	-0.087	0.836
Net Exports	0.068	0.034	0.050	0.848
GDP	0.280	0.029	-0.092	0.783
CPI	0.270	0.021	-0.036	0.746
average	*0.231*	*0.036*	*-0.041*	*0.775*
	Russia			
Interest Rate	0.548	0.349	-0.676	0.779
Real Effective Exchange Rate	0.053	0.145	0.101	0.701
Net Capital Flows	0.018	0.030	0.026	0.927
Net Exports	0.050	0.173	-0.126	0.903
GDP	0.122	0.053	0.049	0.776
CPI	0.067	0.035	0.048	0.850
average	*0.143*	*0.131*	*-0.096*	*0.823*

Table 1: (continued)

	Financial	Goods	Covariance	Internal
	Slovakia			
Interest Rate	0.378	0.423	-0.348	0.547
Real Effective Exchange Rate	0.308	0.180	0.139	0.373
Net Capital Flows	0.148	0.337	-0.124	0.638
Net Exports	0.040	0.048	0.028	0.884
GDP	0.150	0.072	-0.008	0.786
CPI	0.185	0.219	0.173	0.424
average	*0.202*	*0.213*	*-0.023*	*0.609*
	Slovenia			
Interest Rate	0.364	0.159	-0.119	0.597
Real Effective Exchange Rate	0.246	0.095	0.050	0.609
Net Capital Flows	0.076	0.135	0.034	0.755
Net Exports	0.125	0.174	0.007	0.695
GDP	0.005	0.098	0.002	0.896
CPI	0.085	0.028	-0.011	0.898
average	*0.150*	*0.115*	*-0.006*	*0.742*